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Role of a Clinical Hyperbaric Chamber in Support of Research and Military Hyperbaric Operations

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Summary

The DERA Hyperbaric Systems Group is the DERA focus for the research and project support programme for diving, escape and rescue from submarines and for provision of hyperbaric oxygen therapy. The Institute of Naval Medicine is responsible for training military Diving Medical Officers to support MOD Diving operations, submarine escape and rescue operations and Special Forces operations. Jointly they operate the Sir James Watt Hyperbaric Medicine Unit based at the Royal Hospital Haslar. The unit provides:

- Clinical treatment
- Clinical research
- Equipment evaluation
- Training for physicians, nursing and technical staff

Background

The Hyperbaric Systems Group (HSG) is part of the DERA Centre for Human Sciences (CHS). The group is based at Alverstoke, close to the Institute of Naval Medicine (INM) the Royal Hospital Haslar (RHH), the Defence Diving School and the Submarine Escape Training Tank (SETT). The Hyperbaric Systems Group is the DERA focus for the research and project support programme for diving, escape and rescue from submarines and for provision of hyperbaric oxygen therapy.

The Institute of Naval Medicine, Diving and Hyperbaric Medicine Department provides operational medical support to Royal Navy diving activities and provides specialist training in diving and hyperbaric medicine.

The Sir James Watt Hyperbaric Medicine Unit is based at the Royal Hospital Haslar; it is available at 20 minutes notice throughout the year. The unit provides:

- Clinical treatment
- Clinical research
- Equipment evaluation
- Training for physicians, nursing and technical staff

The hyperbaric chamber is an RN 'Type A' chamber modified by a large 'rectangular' door. It is 2.4 metres in diameter and has 2 compartments. The main compartment is 6 m long and the man lock is 2.4 m long. The maximum working pressure is 9 bar (80 msw). The chamber is fitted with a 'medical lock' and electrical and gas penetrations for medical equipment. It can accommodate 6 seated or 2 critically ill patients on trolleys together with appropriate medical and nursing staff and chamber attendants.

The patient breathes oxygen (O_2) at pressures above 1 atmosphere (bar) from the Built in Breathing System (BIBS), hood or ventilator depending on their medical condition.

The chamber is provided with most of the equipment that can be found in a typical Intensive Care Unit (ICU). This includes:

- ventilators
- vital signs monitors

Paper presented at the RTO HFM Symposium on "Operational Medical Issues in Hypo- and Hyperbaric Conditions", held in Toronto, Canada, 16-19 October 2000, and published in RTO MP-062.

- syringe drivers
- infusion pumps
- transcutaneous oxygen monitors
- defibrillator.

All of this equipment has been assessed and certified as fit for use in the chamber.

History of the Hyperbaric Medicine Unit

The unit was established in 1996 as a partnership between:

- DERA, which:
  own and run the chamber,
  provide technical staff, including a 24 hour 'on call' team of operators,
  provide 2 'hyperbaric' nurses and fund the secondment of a nurse from the local civilian hospital.

- Institute of Naval Medicine (INM), that provides:
  the Medical Director who has medico-legal responsibility and hyperbaric expertise,
  a roster of experienced qualified medical officers.

- Defence Secondary Care Agency (DSCA), that:
  ran the Intensive Care Unit (ICU) and other medical specialties,
  owns the current building,
  provides support services and a military nurse.

Each of the stakeholders benefits from the relationship:

Benefits to DERA

The benefits to DERA include a significant non-MOD income. In common with other nations, the UK MOD research budget is declining. There is a requirement to maintain the capability (facilities and staff) required to conduct the MOD work programme but which the MOD cannot afford. The HMU is financially self-supporting and it employs the team required to conduct the MOD work programme. Many of the skills gained in HMU are transferred to other parts of the MOD work programme. The experience gained in the HMU gives our independent ethics committee the confidence that the staff conducting the current diving and submarine escape programme can do so safely.

The establishment of a clinical research programme (e.g. collaboration with Royal Marsden Hospital) broadens the links with academic institutions.

Benefits to INM

The Institute of Naval Medicine is responsible for training military Diving Medical Officers capable of supporting MOD operations including:

Diving operations aboard forward deployed ships (Mine Countermeasures Diving),
Submarine escape and rescue operations (such as 'KURSK'),
Special Forces operations (including newly evolving capabilities).

INM also supports local area commands engaged in underwater and altitude activities; these include:

Submarine Escape Training Tank (SETT),
Defence Diving School,
Fleet Diving Headquarters,
RN Air Medical School,
DERA Alverstoke diving and submarine escape and rescue research programme.

INM also provides diving and hyperbaric treatment advice to UK forces worldwide.

Only by having access to a caseload that includes a significant number of critically ill patients can these medical officers obtain and maintain the skills that they require.

Benefits to the Defence Secondary Care Agency

The HMU provides the Defence Secondary Care Agency with the ability to treat military personnel and train its medical officers and nursing staff.

The DSCA received an income as a result of patients being transferred from HMU to the Intensive Care Unit and other wards at the Royal Hospital Haslar.

DSCA also received payment from DERA for services provided under the terms of a Service Level Agreement.

Benefits to Patients

The Hyperbaric Medicine Unit treats both civilian and military patients. The catchment area for civilian patients is the entire southeastern region of England.

Military patients have been treated for:

Diving injuries (decompression illness)
Necrotising fasciitis
Crush injuries
Re-vascularisation of soft tissue flaps

Conditions which benefit from HBO therapy

The Undersea and Hyperbaric Medical Society endorses the use of Hyperbaric Oxygen for 13 medical conditions:

- Air or gas embolism
- Carbon monoxide poisoning with or without smoke inhalation and cyanide poisoning
- Gas gangrene
- Crush injury
- Decompression illness
- Healing problem wounds
- Necrotising soft tissue infections
- Osteomyelitis
- Radiation tissue damage
- Skin grafts and flaps (where patient is 'compromised e.g. diabetics)
- Thermal burns
- Some intra cranial abscesses
- Exceptional blood loss

The majority of these are of military relevance.

The role of the Hyperbaric Medicine Unit

The HMU has an integrated role providing support for the Royal Navy, Army and Royal Air Force, National Health Service and Defence Evaluation and Research Agency. Its initial objective was to provide training for Diving Medical Officers, an enhanced research capability for DERA, and patient care not readily available in the southeast of England.

Clinical treatment

The HMU provides acute treatments on short notice for injured divers, carbon monoxide intoxication and necrotising fasciitis.

Injured divers from throughout the United Kingdom, English-speaking Commonwealth countries and UK military divers call the Duty Diving Medical Officer (DDMO) who then provides advice and refers the patient to the closest hyperbaric unit with appropriate capabilities. The DDMO carries a cell phone and is manned by INM medical specialists. Specialist trainees may carry the phone under supervision of a consultant specialist. If HMU is the closest appropriate chamber, the DDMO will then see the patient, evaluate the case and treat as indicated. The DDMO is backed by the tertiary care capabilities of Queen Alexandra Hospital in Portsmouth and Royal Hospital Haslar in

Gosport. These capabilities include Intensive Care Unit, accident and emergency department, radiology, anaesthetic and ENT specialists. The DDMO is support by on-call nurses who hold Certified Hyperbaric Registered Nurse (CHRN) and 'intensive care' qualifications. The technicians and dive supervisors supporting chamber operations are exceptionally experienced owing to constant exposure to hyperbaric operations gained from the HSG research programme. Injured divers are usually treated and then admitted for observation and support, with re-treatments provided as clinically indicated. Treated divers are followed in association with their respective general practitioners. Each case is entered into a diving accident database. INM keeps the British Hyperbaric Association diving accident database, receiving additional cases from other member chambers. The database provides a research tool for HMU and INM.

Cases of carbon monoxide intoxication are referred to HMU by area hospital accident and emergency departments. If another appropriately skilled chamber is closer, the patient is directed there. Often, patients are transported to HMU by air or ground from an appreciable distance away, due to area shortages of intensive care beds. These cases are treated twice in the first twelve hours after admission and then further therapy provided depending on recovery. The number of treatments received by any patient are always less than five and rarely more than three.

Cases of necrotising fasciitis are referred from area intensive care units due to Royal Hospital Haslar's unique combination of military plastic surgeons and a hyperbaric facility. The nature of military operations results in as many cases coming from the Ministry of Defence as from the civilian community.

Caseload July 1996 to July 2000

Since the unit opened at RH Haslar, it has treated a total of 478 patients consisting of:

198 Divers,
81 Wound Care patients,
164 patients with Carbon Monoxide poisoning
35 Research volunteer patients

This has involved a total of 1344 treatments, which has resulted in 2990 hours under pressure of which 1076 hours were outside 'normal office hours'.

52 patients were referred to ICU; occupying 290 bed days.
Over 120 patients were referred to general wards; occupying 180 bed days.

To provide the standard of care required to treat critically ill patients (and hence the experience needed by medical officers) a hyperbaric unit must be located in a hospital with an Intensive Care Unit

Clinical research

The academic and research experience within DERA and INM, along with experience gained from treating both NHS and military patients allows for collaborative research funded by both MOD and non- MOD sources. In the UK research funds are frequently tied to studies requiring collaboration of two or more agencies, DERA / INM collaboration with a university or hospital fulfills that criterion.

Typical research projects

A study was designed to assess the hypothesis that early HBO therapy would be of benefit in the treatment of acute ankle injuries suffered by military personnel. This was to be a randomised, blinded sequential clinical trial. Subjects were to be assessed according to well-defined inclusion and exclusion criteria and then randomly assigned to one of three groups. These were; 1) standard medical treatment only; 2) standard medical treatment plus four hyperbaric oxygen treatments at 0.96 bar oxygen partial pressure; and 3) standard medical treatment plus four hyperbaric oxygen treatments at 2.4 bar oxygen partial pressure. Hyperbaric treatments were to follow a standard treatment protocol consisting of 90 minute 2.4 bar exposures. Measurements of functional improvement were to be compared between treatment groups to determine the statistical significance of HBO treatment versus control and 0.96 bar treatment groups. The relevant ethics committees approved the protocol and technical preparations were completed. These included the provision of 2 independent breathing gas systems that allow subjects to breathe either oxygen or a placebo. The allocation of the subject to the active or control groups would be known only to the chamber supervisor who is able to switch the appropriate breathing gas to that subject.

The study has been deferred due to funding/recruitment issues, but the technical preparations were used to advantage in a study conducted in collaboration with the Royal Marsden Hospital.

That study aimed to assess the value of hyperbaric oxygen in the treatment of Radiation-Induced Brachial Plexopathy (RIBP). i.e. radiation damage induced during the treatment of breast cancer.

The study involved 36 volunteer patients who were randomly assigned to an 'active' or 'control' group. Because of the design of the treatment chamber, none of the patients or investigators was aware of which group patients were assigned to. This is believed to be the first large-scale double-blind randomised trial of the effectiveness of HBO conducted in the UK. All of the patients received 30 'treatments' over a period of 6 weeks. Each treatment involved exposure to pure oxygen or to the 'control' gas mixture for 90 minutes at a maximum pressure of 2.4 bar.

There were no statistically significant differences in outcome between the active and control groups, however four patients unexpectedly experienced significant reduction in arm oedema. Two of these patients have sustained this reduction to date (20 months).

A further study has been jointly funded by the MOD and the UK Medical Research Council to investigate effect of HBO on post-irradiation arm lymphoedema in 21 patients. The trial is due to start in November 2000

Training and education

Training programmes for post-graduate physicians and nursing staff evolved naturally as a result of the unique military training opportunities provided by HMU, its relationships with academic and military institutions, the active research programme and the high level of clinical activity.

Diving Medical Officers (DMO) are trained for 3 months under the auspices of the Institute of Naval Medicine. The course is tailored to the individual, as throughput is approximately three to five trainees per year. Training includes; standing duty as the Duty Diving Medical Officer (DDMO), supervising routine and acute treatments at HMU, participating as the Independent Medical Officer for HSG trials work, medical support to the Submarine Escape Training Tank, participating in the Standard Underwater Medicine Course at INM and 'training runs' at HMU, where medical procedures are practiced at pressure up to 6 bar (50msw).

Medical students usually attend HMU for a one-month rotation, participating in patient care and completing a short research topic paper.

Two or three Research Fellowships for Anaesthetic Registrars are to be offered offered each year. Research projects will be sponsored by the Environmental Medicine Unit at INM in collaboration with the University of Portsmouth and by DERA.

Nurses are trained either by completing a Hyperbaric Nursing course at the National Hyperbaric Centre in Aberdeen or the 'Hyperbaric Team Training' course at San Antonio Texas. They are encouraged to qualify for the Certified Hyperbaric Registered Nurse qualification. A minimum requirement for employment at HMU is an intensive care nursing qualification. Continuation training is provided by a one week in three rotation in the local civilian hospital Intensive Care Units and attending academic conferences. HMU nurses also provide medical support to DERA HSG trials. Nursing students are assigned to HMU for one to eight week rotations, depending on their training programme and interest. A training course for Hyperbaric Nurses is currently being developing as a UK /European alternative to that provided in San Antonio.

HMU provides education to the medical community in the form of study days and courses. These are provided in two fora. The first is a HMU funded study day designed specifically to train anaesthetic Consultants, Registrars (Residents) and Senior House Officers in hyperbaric operations. This is tailored to groups of less than fifteen and includes a chamber acquaint dive. All lectures are provided by INM and DERA staff. The second forum is a sponsored study day or course. This study day provides Continuing Medical Education hours to local interested medical professionals. It includes national and international specialists lecturing on hyperbaric topics and presenting research. It is intended to provide weeklong courses under auspices of the Undersea and Hyperbaric Medical Society (UHMS) which will include international speakers such as Eric Kindwall. These courses are designed to attract international participants.

Evaluation and development of medical equipment

The demand for medical equipment for use in hyperbaric chambers has increased with the increasing need to support critically ill patients. This demand is normally from clinicians, who naturally have a preference for the equipment that is available to them on the wards, theatres and Intensive Care Units.

These devices were not originally designed to operate at raised pressure or in the presence of high concentrations of oxygen. If they are to be used in a chamber they must be assessed and modified if necessary.

Ventilators, thermometers, transcutaneous blood gas monitors, patient monitors, defibrillators, infusion pumps and laryngoscopes have all been assessed for use in the HMU.

It was soon apparent that a process was required in order to properly evaluate these devices and document the results. A procedure evolved as the result of work carried out on a patient ventilator for use to 50 metres in HMU.

The procedure was given the acronym '**SELECT**' and it involves:

Specifying the requirement; the clinical requirement will normally be specified by experienced clinical or nursing staff,

Evaluating the risks; these include implosion, explosion, fire, electrical shock or altered performance,

Liaising with the user and the equipment supplier,

Eliminating the risk; this may be by modifying the equipment or by specifying procedures or conditions for its safe use.

The process should be under the control of a **C**ompetent person who has the necessary skill and experience. There may be legislative requirements

On completion of the process, the equipment should be '**T**agged' to show that it has been assessed as suitable for use in the hyperbaric chamber. Some equipment will have required modification and because it will outwardly look the same as any other item of the same type; it must be clearly marked 'for chamber use'.

The dangers of not using properly evaluated and modified equipment should need no further amplification.

The future

The Royal Hospital Haslar is closing; essentially to be replaced by a MOD Hospital Unit at the local civilian hospital (Queen Alexandra Hospital). This is part of a larger development due to be completed in 2006. Meanwhile this closure has resulted in the loss of the ICU and Emergency Room at RH Haslar with consequent effects on patient management and logistics. As an 'Interim' measure the HMU will open a chamber at the local civilian hospital towards the end of 2000 to treat patients requiring HBO and intensive care. This is a standard RN 'Type B' chamber housed in an ISO container and is on loan from the MOD. Ancillary equipment including compressors, gas storage and distribution system are housed in a second smaller container. The facility will be incorporated into an existing building that provides a clinical reception area and access to the rest of the hospital. The unit will be integrated with the Critical Care Directorate and will be supported by all of the services normally found in a major hospital.

The current chamber will continue to be used for ambulatory patients and will remain at RH Haslar until scheduled to be moved and integrated into the newly constructed civilian hospital as the UK MOD focus for Defence Hyperbaric Medicine.

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